TVSS Fusing-The Weak Link?

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The primary technology used to suppress surge currents is Metal Oxide Varistors (MOVs). When an MOV fails, it almost always fails in the shorted mode. Therefore, it is imperative to provide overcurrent protection. Most TVSS manufacturers provide one or more fuses (per phase) upstream of the MOVs to disconnect them from the circuit in the event of a failure. How the manufacturers configure their fusing varies widely. In order for a TVSS system to be capable of suppressing the manufacturer's published surge current rating, the fuses in the unit must be capable of passing the surge current on to the MOVs. **A TVSS unit rated for 400,000 amps per phase which is protected by fuses that will open when exposed to a 35,000 amp impulse, provides no more "real" surge current protection than a properly designed TVSS system rated for 35,000 amps. Where does the remaining 365,000 amps of surge current go? Directly to the critical load! When you consider that a 400,000 amps per phase TVSS unit has a cost of approximately $4,500 and a 35,000 amps per phase TVSS unit has a cost of approximately $550, those owning the 400,000 amps per phase improperly designed units have been taken advantage of (to put it politely). That does not take into consideration the higher risk to the protected load associated with an improperly designed unit.**

Fuses are designed to protect against overcurrent, typically measured in multiple cycles. Transients are measured in fractions of a single cycle. Off the shelf fuses are not designed to pass high energy transients. Many people confuse the AIC current level with the amplitude of transient current the fuse is capable of passing without failure. This is incorrect! **AIC levels have nothing to do with the amount of surge current a fuse can pass without failure.** For example, although a fuse may have an AIC rating of 200,000 amps, the fuse could clear when exposed to a surge current as low as 18,000 amps. Fuse manufacturer's performance tables do not list the

Surge Current Withstandability
Fuse Class "CC", 600 Volt, Dual Element, Time Delay Rated for 30 & 60 Amps

Table 1 Time in seconds	30 amp fuse will open @ ___ amps	60 amp fuse will open @ ___ amps
1000 seconds	36 amps	78 amps
100 seconds	42 amps	130 amps
10 seconds	80 amps	170 amps
1 second	160 amps	400 amps
.1 second	205 amps	540 amps
.01 second	390 amps	910 amps

High energy transients are measured in microseconds (millionths of a second). Extrapolating the data from the fuse manufacturer's table as shown above, produces data for the table shown below.

Table 2 Time in seconds	30 amp fuse will open @ ___ amps	60 amp fuse will open @ ___ amps
.001 second	645 amps	1,500 amps
.0001 second	1,060 amps	2,477 amps
.00001 second	1,750 amps	4,090 amps
.000001 second	2,890 amps	6,745 amps
.0000001 second (1 microsecond)	**4,770 amps**	**11,130 amps**
.00000001 second	7,870 amps	18,370 amps

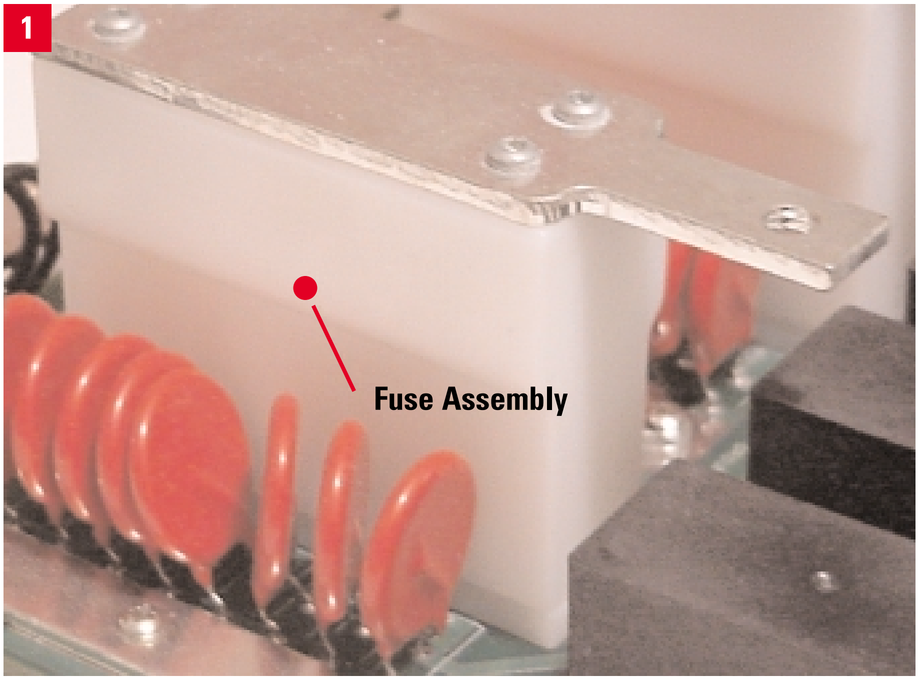
Surge Current Withstandability
Fuse Class "J", 600 Volt, Dual Element, Time Delay Rated for 60 Amps

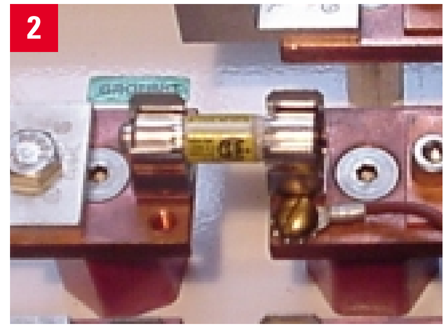
Table 3 Time in seconds	60 amp fuse will open @ ___ amps
1000 seconds	80 amps
100 seconds	145 amps
10 seconds	315 amps
1 second	430 amps
.1 second	650 amps
.01 second	1,050 amps

High energy transients are measured in microseconds (millionths of a second). Extrapolating the data from the fuse manufacturer's table as shown above, produces data for the table shown below.

Table 4 Time in seconds	60 amp fuse will open @ ___ amps
1000 seconds	80 amps
.001 second	1,575 amps
.0001 second	2,365 amps
.00001 second	3,545 amps
.000001 second	5,315 amps
.0000001 second (1 microsecond)	**7,975 amps**
.00000001 second	11,060 amps

continued





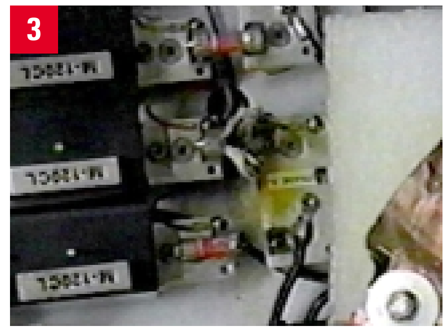


Table 5

Fuse Type	**Extrapolated Maximum Surge Current**	**Tested Maximum Surge Current**
30 Amp, Class CC Fuse	4,770 Amps	18,000 Amps
60 Amp, Class CC Fuse	11,130 Amps	35,000 Amps
60 Amp, Class J Fuse	7,975 Amps	35,000 Amps

current that the fuse will pass in the time period for which impulses are usually experienced. Please refer to tables #1 - #4.

The time base and current numbers in fuse manufacturer's tables are relatively linear. This allows for an easy, and relatively accurate, extrapolation of the data. We have taken the information from fuse manufacturer's performance curves and extrapolated the data to determine the approximate amount of surge current a given fuse will pass. Table #5 shows the extrapolated fuse curve information compared against the failure levels in the fuses we tested.

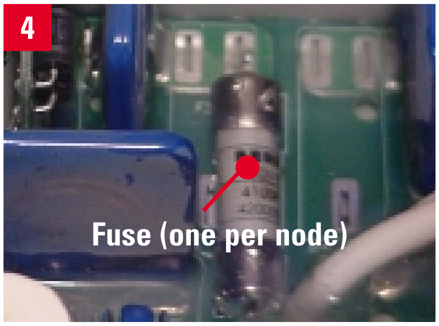
Fusing may be found in two places. Most manufacturers fuse each module or each phase or each mode or, in some cases, each individual MOV. The best design, but also the most expensive, is to individually fuse each MOV. This design has two advantages: 1) If one MOV fails, only one MOV is taken off-line. If you have twenty MOVs protected by a single fuse, a marginal MOV could fail, which clears the fuse, taking not only that MOV off-line, but also an additional (19) MOVs that were still operational. 2) Most fuses will pass no more than 5,000-65,000 amps of surge current, limiting the number of MOVs that can be properly accommodated by a single fuse.

In photo #1, you can see the internal components of a Current Technology TVSS unit rated for 80,000 amps per mode, with eight MOVs per mode, each rated for 10,000 amps. The white rectangular assembly houses the individual fuse chambers, one for each MOV/mode (eight MOVs in the line to neutral mode and eight MOVs in the line to ground mode, per phase). **The fuses within each chamber have been tested and will pass at least 14,000 amps of surge current without failure**. The fuses in this, and every other Current Technology unit, will pass 140% of the surge current rating of the unit. All Current Technology units utilize the same design platform.

Photo #2 shows the fusing in a Brand "A" unit. This manufacturer uses a single, 30 amp, class CC fuse for each module. See photo #3 showing what remained of a 30 amp, class CC fuse after being exposed to an 80,000 amp impulse. This manufacturer's modules are rated for 80,000 to 160,000 amps. Our testing has shown that a 30 amp, class CC fuse will fail when exposed to an impulse of approximately 18,000 amps. **With this design, based on our testing, 80,000 to 160,000 amps (depending on model) of published surge current rating will actually provide no more than 18,000 amps of "real" surge current protection.**

Photo #4 shows the fusing in a Brand "U" unit. In the unit we inspected, this manufacturer uses a custom fuse for each mode. In our testing, this fuse performed similar to a 30 amp, class CC fuse. Depending on the model, this fuse protects 40,000 to 160,000 amps of MOVs. Refer again to photo #3 which shows the results of an 80,000 amp impulse on a 30 amp, class CC fuse. **With this design, based on our testing, 40,000 to 160,000 amps (depending on model) of published surge current rating will actually provide no more than 18,000 amps of "real" surge current protection.**

Photo #5 shows the fusing in a Brand "T" unit. In the unit we inspected, this manufacturer uses a 30 amp, class CC fuse for each phase. Depending on the model, this fuse protects 120,000 to 250,000 amps of MOVs. Refer yet again to photo #3 which shows the results of an 80,000 amp impulse on a 30 amp, class CC fuse. **With this design, based on our testing, 120,000 to**



250,000 amps (depending on model) of published surge current rating will actually provide no more than 18,000 amps of "real" surge current protection.

Many manufacturers, even if they provide fusing for each MOV, offer an optional fused disconnect providing a single fuse for each phase. This is an option with most vendors. **With most manufacturers, the integral disconnect is also the weakest link in the TVSS chain.** It is all well and good to individually fuse each MOV, but if the integral disconnect has only one fuse that will not pass more than 35,000 amps, the TVSS unit with properly designed individual fusing at each MOV is no better than the improperly fused units. The single fuse per phase negates the benefit of the individual fusing at the MOV level. Photo #6 shows the Allen-Bradley 200 amp non-fused disconnect used by Current Technology. Why does Current Technology use a high end disconnect that costs many times more than the typical fused disconnects used by most manufacturers? **The reason is simple, we tested over twenty models of disconnects and found that the Allen-Bradley, 200 amp non-fused disconnect was the only one that was able to withstand a 200,000 amp impulse without failure.** (200,000 amps being the highest level of impulse presently capable of being generated by test equipment.) Every other disconnect we tested failed.

The Current Technology design, with a properly designed integral disconnect and individual fusing at the component level assures that the performance of the protective elements (MOVs and selenium) are not limited by the upstream fusing or the disconnect.

What do most other manufacturers do?

Photo #7 shows the disconnect in a Brand "E" unit rated for 200,000 amps of surge current per phase. This unit uses a 60 amp, class J fuse in its integral disconnect. This manufacturer uses the same disconnect in units rated up to 400,000 amps per phase. Our testing has shown that a 60 amp, class J fuse will fail when exposed to an impulse of approximately 35,000 amps. **With this design, based on our testing, the 200,000 amps of published surge current rating will actually provide no more than 35,000 amps of "real" surge current protection. Accordingly, this manufacturer's unit, rated for up to 400,000 amps of surge current (per phase), actually provides 35,000 amps of "real" surge current protection.**

Photo #8 shows the disconnect in a Brand "U" unit rated for 400,000 amps of surge current per phase. This unit also uses a 60 amp, class J fuse in its integral disconnect. This manufacturer uses the same disconnect in units rated up to 960,000 amps per phase. **Our testing has shown that a 60 amp, class J fuse will fail when exposed to an impulse of approximately 35,000 amps. With this design, based on our testing, 400,000 amps of published surge current rating will actually provide no more than 35,000 amps of "real" surge current protection. Accordingly, this manufacturer's unit, rated for up to 960,000 amps of surge current (per phase), actually provides 35,000 amps of "real" surge current protection.**

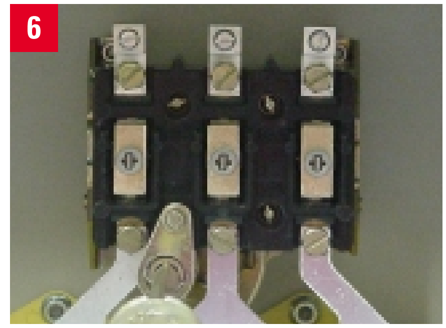
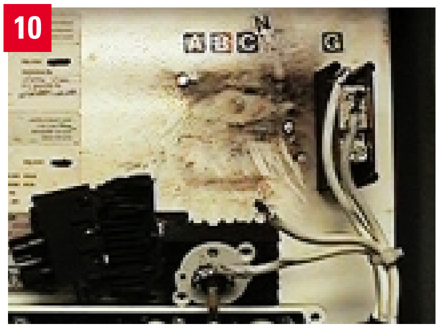
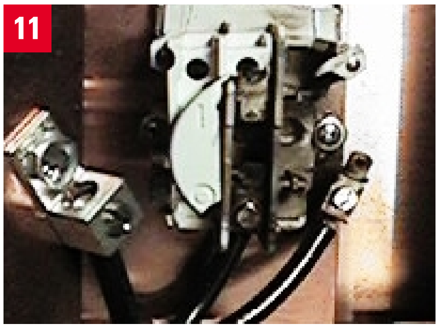


Photo #9 shows the disconnect in a Brand "L" unit rated for 225,000 amps of surge current per phase. This unit also uses a 60 amp, class J fuse in its integral disconnect. This manufacturer uses the same disconnect in units rated up to 337,500 amps per phase. **Our testing has shown that a 60 amp, class J fuse will fail when exposed to an impulse of approximately 35,000 amps. With this design, based on our testing, 400,000 amps of published surge current rating will actually provide no more than 35,000 amps of "real" surge current protection. Accordingly, this manufacturer's unit, rated for up to 337,500 amps of surge current (per phase), actually provides 35,000 amps of "real" surge current protection.**

Photo #10 shows the former location of a fused disconnect after being subjected to an 80,000 amp impulse (1/6th the rating of





the TVSS unit). Note the scorch marks.

Photo #11 shows the remains of a fused disconnect subjected to a 200,000 amp impulse (1/6th the rating of the TVSS unit).

Photo #12 shows the pieces of the same disconnect that were collected from the unit. It is important to note that when this disconnect blew apart, the exposed phase conductors were literally hanging in the air, creating a very unsafe condition. Clearly, standard fused disconnects cannot be trusted to handle the normal surge currents you can expect to see at a building service entrance.

Shown at right is a table with a partial listing of TVSS manufacturers with the number and type of fusing they use:

Manufacturer	Model	Number & type of fuse used	Approximate transient level at which the fuse will clear
Current Technology	All	One fuse for every 10k amp MOV	14k amps per 10k amps of MOV
United Power	SPD	One Ferras, BK-6M30SPR fuse per mode (modes can range from 80k-320k amps).	18k amps per 80k- 320k amps of MOVs
		Optional disconnect has either one 30 amp or one 60 amp fuse per phase (phases rated for 160k-640k amps)	18k up to 240k amps or 35k up to 640k amps of MOVs
United Power	PDX	One Ferras, BK-6M30SPR fuse per module (modules rated for 160k amps).	18k amps per 80k-160k amp of MOVs
		Optional disconnect has one class J fuse per phase (phases rated for 160k-960k amps)	35k amps per 160k-960k amps of MOVs
EFI	Titan SE	One class CC fuse per module (modules rated for 80k each)	18k amps per 80k amps of MOVs
EFI	TBP	One 60 amp, class J fuse per phase in optional disconnect	35k amps per 200k amps of MOVs
Tycor (also marketed by Cutler-Hammer)	Clipper, CPS-B & CPS-S	One 30 amp, class CC fuse per phase (phases rated for 100k or 120k amps)	18k amps per 100k-120k of MOVs
APT (also the standard offering of Square D & Siemens)	All main service type units	One 30 amp, class CC fuse per module (80k-160k amps)	18k amps per 80k-160k amps of MOVs
Liebert	Interceptor Series	One fuse wire per MOV	Not tested (see note below)
		Optional Disconnect has one class CC per phase (phases rated for 100k-400k amps)	35k amps per 100k-400k amps of MOVs
Leviton	52000 & 57000 Series	One class CC fuse per phase (phases rated for 90k-200k amps)	35k amps per 90k-200k amps of MOVs
Leviton	42000 Series	One Microtemp thermal overload per phase (50k amps)	<6k amps per 50k amps of MOVs

Note on the Liebert modules: During the testing on Liebert modules their module fuse links experienced multiple failures that were not due to the MOV failing.

Conclusion

Presently, there are units available in the marketplace with published surge current ratings up to 960,000 amps per phase that will suppress no more than 35,000 amps before taking themselves off-line due to fuse failure. These units can cost up to $10,000, yet provide no more real protection than a properly designed unit rated for 35,000 amps costing no more than $550. Failure to insure that a TVSS unit will suppress the published surge current is a waste of your client's money and unnecessarily exposes them to the risk of damage from high energy transients that would otherwise be minimized by a properly designed system.

It should be obvious to you by now that most manufacturers do not fuse their TVSS units to allow the system to suppress that manufacturers published surge current ratings. How do you insure this type of unit does not end up on your job? The obvious solution is to only accept manufacturers whose fusing is designed to allow the TVSS unit to suppress the rated capacity of the equipment. One way to insure this is to require the TVSS manufacturer to supply you with a copy of their NEMA LS-1 independent test documentation. Obviously, if a manufacturer can provide a legitimate test report, their fusing has been properly designed. Be very careful! Some manufacturers only conduct NEMA LS-1 testing on their modules. They do not include the fusing or disconnect.

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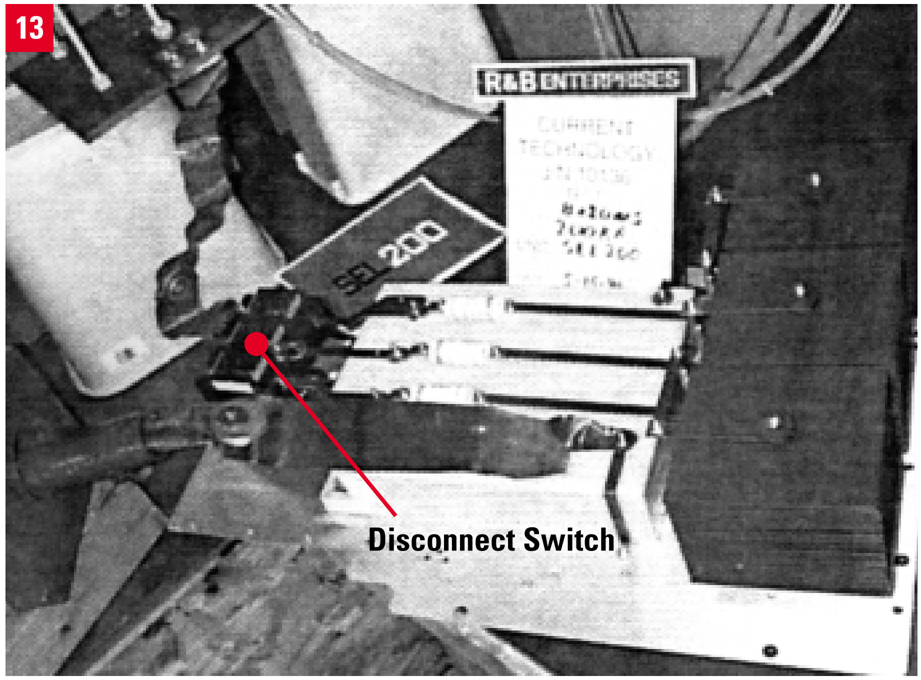

Excerpt from NEMA LS–1 test report
The test item was the Current Technology Surge Suppressor, Model Number SEL200-277/480-3GY-10-DM, Part Number 900-0177-005-30

Photo # 13 shows a Current Technology unit being tested to NEMA LS-1 standards. You will note that the disconnect is included in the test and shown in the photo. Additionally, you can see in the excerpt from the test report that the suffix "DM", signifying integral disconnect, is included in the model number referenced in the test. Make sure, when reviewing NEMA LS-1 test reports, a photograph of an entire unit, including fusing and a disconnect, is part of the report, and a model number of an entire unit, including the disconnect is referenced. Additionally, you can require, as part of your submittals, that the manufacturer provide information regarding the quantity and rating of the fuses used in their units. Compare this information to the known capacity for 30 and 60 amp, class CC and class J fuses and make your determination.

Questions?

If you have any questions regarding fusing in TVSS units please call Precise Power, Inc. @ 1-800-578-5702.